因應非生物逆境之栽培與育種策略：以台灣環境之考量及稻作研究爲例

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氣候變遷正對台灣的作物產量與品質造成威脅。研究顯示台灣氣溫每 10 年上升 0.15℃，高於全球的平均暖化速度。近 30 年內的暖化速度更是明顯，年均溫每 10 年就增加 0.36℃，夜溫增加是造成暖化的主因。模擬研究顯示，台灣未來溫度估計每 10 年可增加 0.1℃至 0.3℃，明顯超過全球平均暖化速度；此外，過去百年來的日照輻射量也不斷減少。預估台灣正面臨氣溫增加、日溫差縮小、高等溫線向北(及高海拔)移動、乾濕季明顯、強降雨及熱浪頻率增加的變遷趨勢，對各種作物之分布、生產型式、產量、及品質都將造成顯著的衝擊。

以稻作爲例，在稻作栽培上過去 10 年內，水稻栽培期間的日、夜最高溫之發生頻率正持續增加，且多發生於一、二期作的穀粒充實期，此氣溫攀升正顯著威脅台灣的水稻產量與品質，可能已造成相當地區之未熟粒率/白堊質粒率增加。統計數據顯示，部份台灣農民已經「察覺」此氣候暖化的趨勢，正調整栽培管理方式以因應暖化趨勢。近 10 年來台灣南部地區農民的一期作的插秧時間明顯提前，二期作的插秧時間略爲延後，此栽種時間的調整可使兩次栽培期的穀粒充實期面對溫度較低，進而穩定產量及品質。研究也顯示，適當的調整栽培期、栽培密度、及肥培管理，可降低暖化所造成的衝擊，而吾人正以試驗找出水稻重要經濟性狀對溫度反應之關鍵溫度，可依此規劃出適當的栽培措施。

在育種方面，自台灣大量引進日本型水稻並成功育種馴化以來，現今台灣超過 90%以上的栽培稻種皆屬於溫帶型之日本型品種。基於台灣亞熱帶的地理位置，台灣育成的日本型稻種被認爲對光週期的敏感性較低，且對高溫環境的適應性較高，但目前台灣發展耐高溫及其他非生物逆境的育種計畫仍在啓蒙階段。人工氣候室初步篩選試驗的結果顯示幾乎所有現代栽培種皆不耐高溫(33℃)，低小穗花稔實率及高白堊質粒率是高溫造成各品種產量減低及品質下降的主要因素，建議需要廣泛的引進相關基因，以改良台灣日本型稻的高溫及其他非生物逆境耐受性，本報告也將呈現穀粒充實期對高溫之生理及分子反應機制，並提出育種之理想型的內涵。

台灣處於亞熱帶氣候環境，在農業生產上也屬於氣候變遷之高風險地區，作物之調適措施必需積極進行。建議此調適措施在研發上依序包括: 確認各作物敏感的重要

經濟性狀、瞭解這些重要性狀的耐性生理及分子機制及對環境因子反應之關鍵條件、調整及規劃以永續性爲基礎之栽培操作、建置快速之育種材料及基因庫的氣候因子篩選設施與技術流程(溫度、風速、降雨等)、進行整合有效的育種計畫。重要的是，此調適措施必須由跨領域間的密切合作方能成功，這才是最關鍵的挑戰，尤其是台灣。

Adaptation of Crop Cultivation and Breeding to Abiotic Stresses: With Aspect of Taiwan's Environment and Case Study in Rice

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It is found that the temperature has been increasing by the rate about 0.15℃/10 year, which is faster/higher than the global average rate of warming. The warming status is even significant during the recent 30 years with rate of 0.36℃/10 year. Increase of night temperature is the main course for the warming trend. In addition the radiation has also decreased during past 100 years. With respect to the future, the temperature is estimated to increase by 0.1 – 0.3℃/10 years in Taiwan, which is also faster than the trend of the globe. In addition, higher frequency of heat wave and heavy precipitation is also estimated to increase in the coming years. All the climate changing trends have been imposing significant challenges to the management systems, yield, and quality of Taiwan crops.

In case of rice, the trends of climate change have affected the yield, timing of harvesting, and quality of rice production. Statistic survey showed that the average temperature and maximum temperature have been increasing during recent 10 years for both crop seasons. The increased temperature may have been causing an increase of immature/chalky grain rate, and decrease of market value. It is interested to note that farmers may already 'feel' the trend of climate warming, and are adjusting their culture management in coping with the trend of warming. Statistic review revealed that the timings of transplanting for the 1st crop and 2nd crop are moved earlier in recent 10 years, especially in the main rice production regions of Taiwan. The adjustment may lead to a lower temperature at grain filling stage for both crop seasons, and result in a 'stable' yield and quality. Our study also reveals that modification of plant density may also improve adaptation to high temperature in yield and quality. Currently breeding program for high temperature tolerance is still at its infancy in Taiwan. Preliminary results from screening trails at phytotron reveal that almost all of modern cultivars are vulnerable to high temperature. Low spikelet fertility and high chalky rate are main factors for the low grain yield and quality in response to high temperature. A broad Introduction of adapted genes is necessary to improve the high temperature tolerance. Based on the physiological

approaches, an ideotype has been proposed for the breeding improvement of high temperature tolerance of Taiwan japonica cultivars.

To elevate the adaptation capability, integrated strategy should be urgently constructed and implemented. Crucial processes of the strategy include: identifying target/vulnerable economic traits of crops, understanding responding thresholds of the target traits, restructuring agronomic management with concept of sustainable intensification, constructing high throughput facility and phenotyping tools for screening adapt traits of breeding and gene bank materials, and conducting effective breeding process immediately. A close cooperation among scientists from multiple disciplines is also vital for the success of the adaptation of our crop production to the occurring of climate change in Taiwan.